Leuchter, S., & Urbas, L. (2003). Modeling dynamics and timing for operating human-machine systems. In F. Detje, D. Dörner, & H. Schaub (Eds.), *The Logic of Cognitive Systems. Proceedings of the Fifth International Conference on Cognitive Modeling* (pp. 279-280). Bamberg: Universitäts-Verlag. http://www.safety-critical.de/doc/iccm03.pdf

Modeling dynamics and timing for operating human-machine systems

Sandro Leuchter (sandro.leuchter@zmms.tu-berlin.de)
Leon Urbas (leon.urbas@zmms.tu-berlin.de)

MoDyS Research Group, Center of Human-Machine Systems, Technische Universität Berlin
Jebensstr. 1, D-10623 Berlin, Germany

Abstract

The aim of this contribution is to foster application of architectural bound cognitive modeling in engineering of human-machine systems. Although well suited with its memory system and sub-symbolic features a major concern that constricts application in engineering is the handling of dynamics, time, and duration in ACT-R. We draw conclusions for extensions in ACT-R for linking ACT-R models to task environment beyond ACT-R/PM, recall of duration information, and scheduling.

Introduction

An important current trend for the ACT-R community is to apply cognitive modelling to engineering problems like human computer or machine interaction. Important developments of the architecture that are necessary to do so are PM for integration to the task environment and new ways of goal management. An area that still needs attention is timing for operating human-machine systems. With this contribution we want to promote the application of cognitive architectures for engineering dynamic human-machine systems (HMS).

Human-Machine Systems

Technical systems are often not fully automated but operated by humans. The term human-machine system denotes not only systems in which at least one human operates a technical system, but emphasizes the interaction between human and machine. Typically the technical system is complex and shows a continuous dynamic behaviour that is influenced by interventions of its operator. While former research on HMS has focused on physical and ergonomic characteristics of the interaction for optimizing construction and force feedback properties, today the main topic is estimating consequences of automation. Since technical systems are getting more complex often cognition, memory span, and mental models are being of concern. Systems that are analysed and developed from an HMS viewpoint are typically in high risk environments.

Objective

The objective for modeling behavior of HMS operators is to facilitate simulation based design support, training, and deployment in assistive technology.

Simulation based design support

In the development process of HMS' it is cost efficient to detect design flaws as early as possible. Thus tests are conducted with prototypes or even mockups instead of finished products. The use of simulations of the technical system is common practice in testing e.g. in automobile industry. Additionally simulations of cognitive capabilities of the potential user are effective for questions about human reliability. They can be efficiently applied to large scale multi-user scenarios like computer generated forces or when a single prototype test is very expensive like in aircraft cockpit automation.

Training

Insights from simulations of different strategies formalized in cognitive models can be measures for the difficulty of learning and executing each strategy. These measures can be used to decide which procedures to train for operating HMS.

Deployment in assistive technology

Besides using simulations of cognitive processes as knowledge based support system (perfect cognitive models making no errors are *expert systems*) realistic (error making) cognitive models have the potential to be deployed in adaptive automation systems. Such systems adapt their behavior to external conditions normally detected in the technical system or its environment. Taking not only the technical or environmental state but also that of the operator into account leads to a more effective task allocation between automation and human operator. Realistic cognitive models running parallel to the HMS can be used to predict current or future operator states. A famous example for this kind of automation are intelligent tutoring systems (e.g. Leuchter & Urbas 2002).

The rationale of the use of the cognitive architecture ACT-R is to make the modeling process more efficient by introducing a priori constraints on memory and processing.

Timing

If cognitive models are applied in engineering it is usually the aim to predict frequencies of erroneous production selection or memory slips or execution or learning durations for the whole task (e.g. within the GOMS framework). But there are also errors according timing and thus the need not only to model adaptive sequences of production selection but also the use of time and duration in conditions of productions.

An example for such a modeling demand is in process control: Sometimes a task has to be abandoned when too much time has elapsed. Thus duration has to be recalled in productions' conditions. To achieve this the system's real time would have to be retrieved and stretched or compressed according to the current workload.

Another example is in air traffic control. Scheduling the processing of different aircraft and their constellations depends on timing: It is important to update the state (mostly position and altitude) of the objects as often as possible. But due to the other subtasks aircraft can only be monitored from time to time. But the need to update an object's features in the mental representation gets more important the longer the object has not been modified. Thus decay of activation depending on accesses to chunks is a contrary concept.

Chunks representing such special elements of the situation under supervisory control have to be used in a certain way: Special productions have to refresh their activation depending on the current need to update it. Niessen et al. (1998) achieve this behavior through direct manipulation of activation parameters from outside ACT-R in the *production-cycle-hook*.

Extensions to the ACT-R Architecture

On the basis of a brief review of these tasks and their requirements for scheduling and multi-tasking some needs for ACT-R can be drafted to fit it to modeling operator cognition in complex dynamic human-machine systems. We are currently implementing these extensions for modeling process control of chemical plants.

Linking and Embedding to Task Environment

Although ACT-R/PM made it possible to connect a model with a task environment there are problems for engineering: Normally there exists a big simulation or an API not accessible from LISP or making it hard to create a GUI within the LISP process. While one can cope with this restriction it would be more efficient to embed an ACT-R model into a higher-level framework for the "normal" control of a system and only execute a specialized ACT-R sub-model for questions like memory errors from there. This would help controlling a real world situation with a simple outer model (without ACT-R) and only pay attention to special situations for that a more precise ACT-R model would be built.

Inside the ACT-R model there were less need for multi-tasking and scheduling and additionally communication with the task environment could be achieved through appropriate instantiation of chunks in the model during its start-up.

Recall of Duration

A new function for recalling duration information has to be added. Setting named reference points that are stored as chunks in the working memory and thus can be forgotten or confused allows for retrieving elapsed time since setting it.

Perception of time is depended to the workload and the "mode": If concentrating on duration measurement high workload leads to underestimating, if recall is retrospective high workload leads to overestimating elapsed duration. Recall has to be possible in both modes and must be stretched or compressed according to subgoaling.

Scheduling

Tasks are to be represented and executed as chunks from a ACT-R "middleware" such as ACT-GOMS (Schoppek et al. 2000). But in contrast to ACT-GOMS it must include a scheduler for subtasks. They are to be marked interruptible and immediate during modeling time. Priority and urgency like in PDL could further guide the scheduling process.

An additional requirement in chemical plant control is that some tasks may not be carried out in parallel with others and that there are other dependencies possible. But a scheduler should not take also such information into account but it had to be modeled explicitly because this is an important source of control errors.

Acknowledgments

This work is supported by Volkswagen Foundation in the program "Junior Research Groups at German Universities".

References

Leuchter, S., & Urbas, L. (2002). Simulation Based Situation Awareness Training for Control of Human-Machine-Systems. In V. Petrushin, P. Kommers, Kinshuk, & I. Galeev (Eds.), *IEEE International Conference on Advanced Learning Technologies. Media and the Culture of Learning. Kazan, Russia: Sep 9-12, 2002* (pp. 34-39). Palmerston North, New Zealand: IEEE Learning Technology Task Force.

Niessen, C., Leuchter, S., & Eyferth, K. (1998). A psychological model of air traffic control and its implementation. In F. E. Ritter & R. M. Young (Eds.), *Proceedings of the Second European Conference on Cognitive Modelling (ECCM-98)* (pp. 104-111). Nottingham: Nottingham University Press.

Schoppek, W., Boehm-Davis, D.A., Diez, M., Hansberger, J., & Holt, R.W. (2000). Letting ACT-R fly - A model of the interaction between trained airline pilots and the flight management system. In *Proceedings of the Seventh Annual ACT-R Workshop 2000*, Carnegie Mellon University, Pittsburgh, PA.